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Effectiveness of Spray Adjuvants on Reduction of Spray Drift

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Abstract.
Numerous drift reduction adjuvants and spray deposition aids are available to applicators of crop production and protection chemicals. Performance of many of the newly introduced drift control adjuvants has not been well documented for aerial application. Four drift control adjuvants were selected for drift studies in aerial applications. Deposition, downwind drift, and droplet spectra characteristics in a cotton canopy were collected on water sensitive paper (WSP) and Mylar cards for measurement and analysis. The deposition, droplet size, droplet coverage, and total drops were highly correlated to the drift distance and treatments or adjuvants. Deposition on the monofilament lines decreased as sampling height increased for each treatment. The results will aid aerial applicators in selecting drift reduction agents to meet the drift mitigation criterion for a given application.

Keywords. Aerial application, spray drift, adjuvant, droplet size, cross wind

Introduction[1]

Spray drift from the aerial application of pesticides has been recognized as a concern for the environment. Even though a better understanding of the variables associated with spray drift exists, it is still a challenging and complex research topic. Environmental variables, equipment design issues, many application parameters, and numerous interactions make it difficult to completely understand drift related issues (Smith, et al., 2000; Wolf, et al., 2005). Spray droplet size has long been recognized as the most important variable that aerial applicators can influence to mitigate spray drift from the application site (Yates, et al., 1976; Bouse, et al., 1988; Bird, et al., 1996; Anon., 1997). Sprays with coarse droplet spectra drift less than sprays with fine droplet spectra, but applicators must also consider droplet size for optimum efficacy of the applied material. Spray nozzle selection is the first factor for aerial applicators to consider in determining spray droplet size or spectrum. Secondary considerations are those operational factors that influence atomization such as nozzle angle or deflection relative to the airstream, aircraft speed, and spray pressure. The auxiliary factor often considered for drift reduction by aerial applicators, after nozzle selection and operation, is spray mix additives or adjuvants. Materials added to aerial spray tank mixes that alter the physical properties of the spray mixture affect the droplet size spectrum (Hoffmann, et al., 2003).

There are many types of spray adjuvants with classifications such as surfactants, spreaders, stickers, deposition aids, activators, humectants, antifoamers, wetting agents, and drift reduction agents. Soaps and oils of various types were some of the materials first used as spray adjuvants, but products designed and formulated for specific purposes have been available for several years. The modern era of adjuvant science was bolstered by the First international Symposium on Adjuvants for Agrochemicals in 1986 and subsequent publication of the symposium proceedings (Chow, et al., 1989). Spray drift became a significant issue with the introduction and use of phenoxy herbicides and the associated off-target damage to sensitive vegetation. Spray drift continues as an industry issue with enhanced concerns about environmental trespass, threatened and endangered species, and associated regulatory actions (Mulkey, 2001). Water soluble synthetic polymers were the dominant components of most of the adjuvants that were first designed and marketed for spray drift control (Bouse et al., 1988). These materials were generally effective in increasing the average spray droplet size and sometimes, but not always in reducing the content of fine droplets that are more prone to drift from the application site. More recently, natural and other polymers, often formulated as dry materials have been marketed for spray drift reduction. There is only limited technical literature on aerial performance of the newer drift reduction adjuvants (Hewitt, 2003; Kirk,

[1] Mention of trademark, vendor, or proprietary product does not constitute a guarantee or warranty of the product by the USDA and does not imply its approval to the exclusion of other products that may also be suitable.

2003; Wolf et al., 2002, 2003, 2005), since much of the previous research has focused on ground application systems.

Objective

The objective of this study was to measure and quantify the effect of different spray adjuvants on the downwind deposition and transport of aerially applied sprays.

Materials and Methods

Adjuvants

Four adjuvants, all classified as surfactants, were used in this study. The spray solution consisted of water, EC Blank formulation, fluorescent dye (15 g/acre), and a spray adjuvant (Treatments). The fluorescent dye was used as a tracer to measure the deposition and downwind movement of the spray during the tests. Targeted spray rate was 3 gal/acre. For each spray treatment, the aircraft was loaded with 60 gallons of spray containing 300 g of dye. The EC blank tank mixture consisted of 90% water, 9.2% Aromatic 150, 0.64% Toximul 3453F, and 0.16% 3454F. The treatments with the four adjuvants are shown in Table 1. Treatment 2 was the baseline tank mixture with no adjuvant added.

Table 1. Treatments with adjuvants, company information, and rate.

Treatment	Adjuvants	Company	Rate
T1	Array	Intec Agro Products Inc.	9 lb/100 gal
T2	EC Blank only	Exxon/Stephan	
T3	In-Place	Wilbur-Ellis Inc.	2.5 gal/100 gal
T4	Vector	Rosen's Inc.	2 lb/100 gal
T5	Control	GarrCo Products Inc.	2.4 oz/100 gal

Spray Treatment

Spray application treatments used CP-11TT flat fan nozzles (CP Products Company, Tempe, AZ) set to the number 15 orifice and 75 degree deflection. All treatments were made using an Air Tractor AT-402B (Air Tractor, Inc., Olney, TX) operated at 135 mph and a spray pressure of 35 psi and 65 ft swaths with a 10 foot release height. Each treatment was replicated three times over a cotton canopy with each replication consisting of a one spray pass with the right wing on the downwind side.

Study Layout

The in-swath deposition and downwind movement (i.e., drift) of applied material released from the aircraft were measured by flying the aircraft perpendicular to the prevailing wind. Sampling stations were placed parallel to the wind (fig. 1). There were three sampling lines (A, B, and C) for each replication. Lines B and C were 12 m apart. For each sampling line, in-swath deposition samplers were placed directly under the aircraft and were located at 15, 10, 5, and 0 m upwind from the downwind edge of the spray swath (designated as -15, -10, -5, and 0 m). At each location, a mylar card and water sensitive paper (WSP) card were placed at crop height. Downwind deposition samples were placed 5, 10, 15, 25, and 50 m downwind from the edge of the spray swath. Mylar cards and WSP were placed at canopy height at the 5 and 10 m locations, while only mylar cards were placed at the 15, 25, and 50 m locations.

In addition to the in-swath and downwind deposition sampling, at 50 m (186 ft) from the downwind edge of the spray swath, two vertical towers were positioned 12 m (39 ft) apart. Monofilament line was suspended between these towers at 2, 5, and 10 m (6.6, 16.5, and 33 ft, respectively) (fig. 1). The lines were parallel with the flightline and provided a measure of the airborne component of the spray. String samples were collected on the 1st and 2nd reps of each treatment.

Data Analysis

After each treatment replication, sufficient time was allowed for the spray material to move downwind and the material deposited on the cards and papers to dry (approximately 5 minutes). The WSPs (2.5 cm X 7.5 cm) were allowed to dry and placed in labeled film negative sleeves. WSPs were analyzed using DropletScan TM (WRK, Inc. and Devore Systems Inc.). Deposition, $D_{V0.5}$, $D_{V0.1}$, DV0.9 percent area coverage, and number of drops per card were determined. The D_{Va} values are the droplet diameters (µm) where (a x 100) % of the spray volume is contained in droplets smaller than this value (ASAE, 2005).

Each exposed mylar card (100 cm^2) was placed in a labeled plastic bag, stored in an ice chest, and transported to the laboratory for quantification. The cards were exposed to sunlight for less than 15 min following an application; therefore, no appreciable degradation of the fluorescent dye would be expected. Twenty ml of ethanol was pipetted into each bag, the bags were agitated, and 6 ml of the effluent was poured into a cuvette. The cuvettes were then placed into a spectrofluorophotometer (Shimadzu, Model RF5000U, Kyoto, Japan) with an excitation wavelength of 453 nm and an emission at 488 nm. The fluorometric readings were converted to µg of dye/cm^2. The minimum detection level for the dye and sampling technique was 0.00007 µg/cm^2.

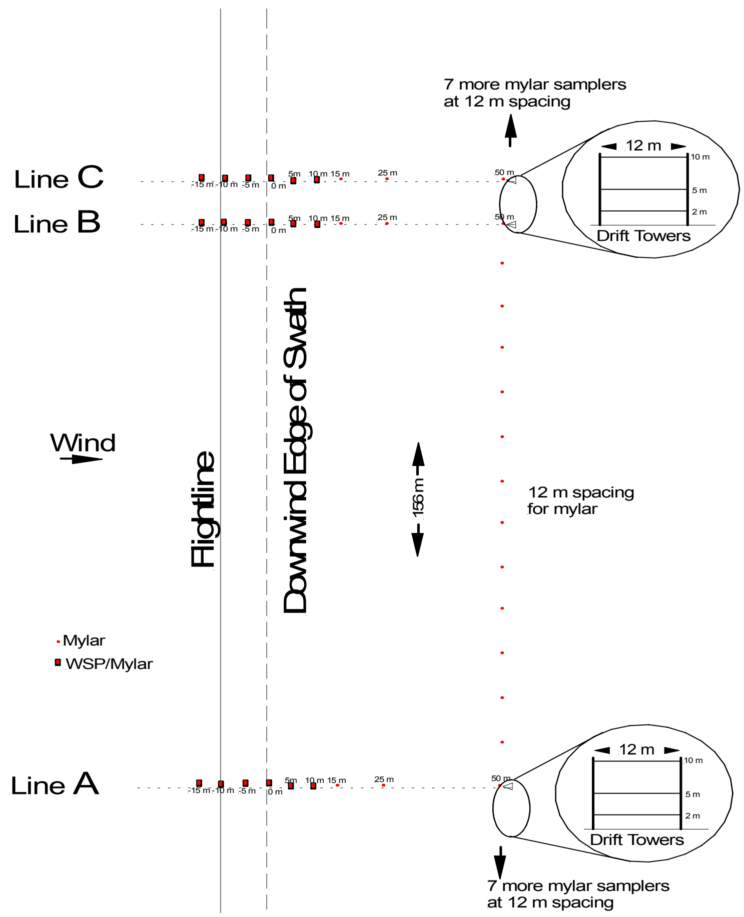


Figure 1. Test site layout showing flight line (dashed line) and sample locations (boxes).

After each replication, the towers were lowered and the monofilament lines were collected on dedicated reels. Each reel was placed in a labeled plastic bag, stored in an ice chest, and transported to the laboratory for quantification. After pipetting 40 ml of ethanol into each bag, care was taken to thoroughly wash the monofilament line and the spool in the bag to allow all of the dye to be dissolved into solution. Sample analyses and quantifications were performed as described for the mylar card samples.

Field Plots

All tests were conducted in cotton fields (30°43’13” N, 96°33’38” W, and 60 m (200 ft) above MSL) near College Station, TX in the summer of 2006. The cotton was planted on 0.9 m (36 in) rows. A total of 9 tests were conducted with the average canopy characteristics from 3 plants at nine locations measured at the time of each tests are shown in Table 2.

Table 2. Cotton height and width (cm) at different sample location

Location	-15m	-10m	-5m	0	5m	10m	15m	25m	50m	Average
Plant Height	85	80	89	83	85	90	88	82	84	85
Plant Width	65	62	70	61	68	71	71	61	65	66

Meteorological Monitoring

Meteorological data were monitored throughout the study using an RM Young Model 8100 Ultrasonic Anemometer and a Campbell Scientific HMP45C temperature and relative humidity probe mounted in a radiation shield. Both sensors were mounted on a stand and set 2 m above top of canopy and were located approximately 20 meters downwind of the flight line and adjacent to sampling line. Data was collected at 10 Hz and averaged based on a four minute time period corresponding to one minute prior to application and three minutes following application.

Statistical Analyses

All the statistical analyses were performed using the Proc GLM procedures in SAS (SAS Institute, 2005). Treatment means at the three heights of the monofilament line samples were separated by Duncan's Multiple Range Test ($\alpha = 0.05$).

Results and Discussion

Meteorological Data

Data for each test/replication combination are presented in Table 3. Mean wind speeds were consistent across all test replication combinations. Wind angles varied between 1° and 16° and were well within the ±30° recommended by ASAE S561.1 (ASAE, 2005). Mean temperature and relative humidity values remained fairly constant with temperature gradually increasing and relative humidity gradually decreasing as the day progress, as would be expected.

Table 3. Meteorological data measured and calculated for each test/replication combination.

Test	Rep	Mean Wind (m/s)	Wind Angle Deviation[a] (deg)	Mean Temperature (C°)	Mean Relative Humidity (%)
1	1	3.4	13.4	31.3	62.6
1	2	3.2	10.1	31.3	62.5
1	3	3.1	9.9	31.7	61.6
2	1	3.2	11.4	31.4	61.5
2	2	3.2	16.7	31.7	60.5
2	3	3.1	13.6	32.0	59.4
3	1	3.1	15.2	32.2	58.0
3	2	3.1	14.2	32.4	56.9
3	3	3.1	12.3	32.7	55.9
4	1	3.0	9.0	33.0	54.6
4	2	3.1	10.0	33.2	53.4
4	3	3.1	8.1	33.5	52.4
5	1	3.1	6.9	33.7	51.5
5	2	3.1	3.3	33.9	50.8
5	3	3.1	1.1	34.1	50.1

[a] Wind angle deviation corresponds to angle of wind relative to sampling line.

Samples -15 – 50 m from In-swath and Downwind Edge of Swath-Horizontal Mylar Tests

The Mylar samples detected essentially no droplet depositions beyond the 25 m (82 ft) sample locations (fig. 3). Outside of the intended treat area,

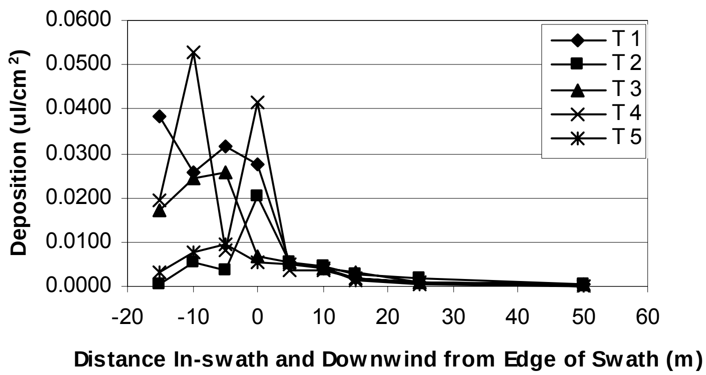


Figure 2. In-swath and downwind from edge of swath deposit as measured on horizontal Mylar cards. The centerline of flight was at -10 m (33 ft).

treatments 3 and 5 had the least deposition. Treatment 4 resulted in the greatest downwind deposition, followed by treatments 1 and 2. All the treatments had similar deposition values from 5 – 25 m.

Samples -15 – 10 m from In-swath and Downwind Edge of Swath-Horizontal WSP Tests

Deposition

The deposition values by distance by treatment from the in-swath and downwind edge of swath are shown in Figure 3. The deposition generally decreased as distance downwind from the spray swath increased, except for Treatment 2 which had a slight increase at the 5 m location. Treatment (α <0.0001) and distance (α <0.0001) effects on deposition as measured by the WSP were highly significant. The mean deposition was 0.54, 0.47, 0.81, 0.73, and 0.96 gpa for Treatments 1-5, respectively. Treatments 3 and 5 resulted in the highest deposition amounts, while Treatments 1 and 2 (EC Blank) had the lowest deposition.

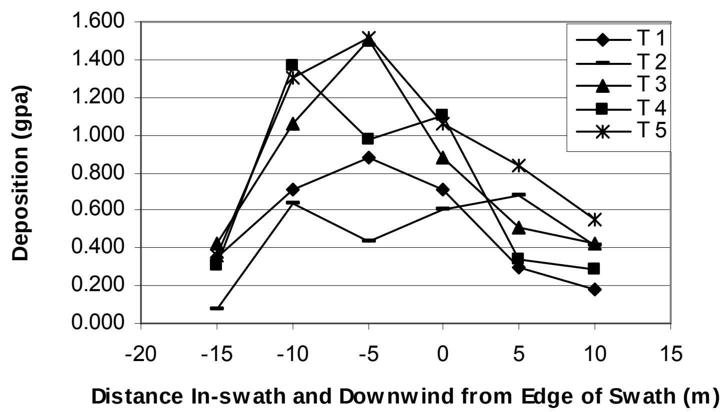


Figure 3. In-swath and downwind from edge of swath deposit as measured on horizontal WSP cards. The centerline of flight was at -10 m (33 ft).

Means separation results from Duncan's multiple range tests for deposition, $D_{V0.5}$, percent area coverage, and number of drops are given in Table 4.   With respect to deposition, all the treatments were significantly different from treatment 2 (EC blank) with the exception of Treatment 1.

Table 4. Duncan's multiple range tests in samples -15-10 m in-swath and downwind edge of swath for deposition, DV0.5, percent area coverage, and number of drops as measured by the WSP.

Treatment	Deposition	$D_{V0.5}$ (μm)	Percent Area Covered	Number of Drops
T1	dc	b	b	b
T2	d	c	b	ab
T3	ab	c	a	a
T4	bc	b	ab	b
T5	a	a	a	b

Column means with the same letter are not significantly different.

Droplet Size

The droplet size values ($D_{v0.1}$, $D_{v0.5}$, and $D_{v0.9}$) by distance by treatment from the in-swath and downwind edge of the swath are shown in Figures 4 and 5. Treatment (α <0.0001) and distance (α <0.0001) effects were both highly significant. The droplet size generally decreased as distance downwind from the spray swath increased, except Treatment 2, which had a slight increase at 5 m location. The smaller droplets were deposited at further distances downwind than the larger droplets. Treatment 5 had the largest measured droplet spectra (fig. 4). Treatments 1, 4 and 5 were significantly different from treatment 2 (EC blank). There were no significant differences between Treatments 2 and 3. The mean $D_{v0.5}$ values were 273, 197, 222, 271, and 305 (μm) for Treatments 1-5, respectively. Treatment 2 (EC Blank) had the smallest $D_{v0.1}$, $D_{v0.5}$, and $D_{v0.9}$.

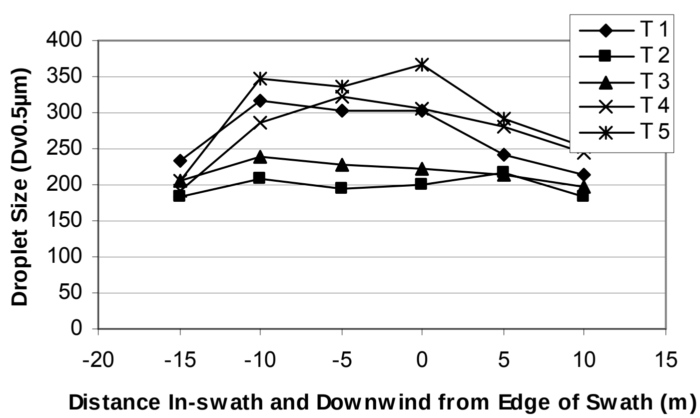
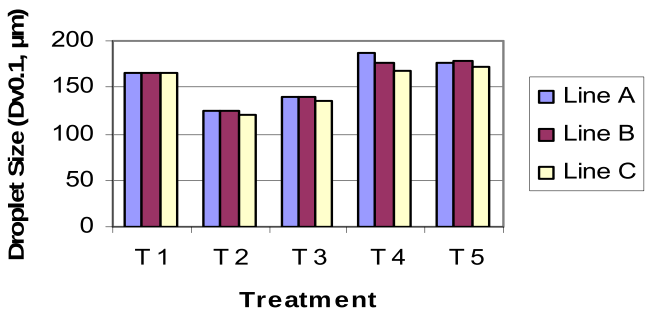


Figure 4. In-swath and downwind droplet size parameters ($D_{v0.5}$ or VMD) as measured on the horizontal WSP cards.



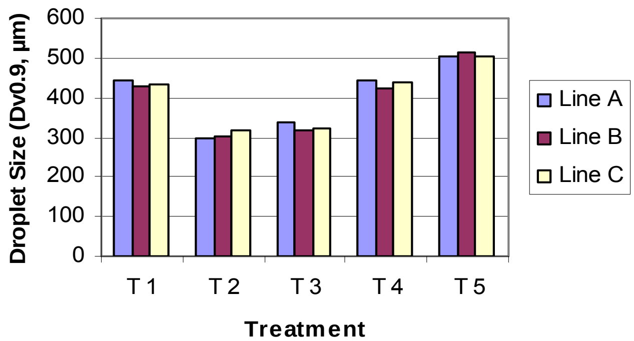


Figure 5. In-swath and downwind droplet size parameters ($D_{v0.1}$ and $D_{v0.9}$) as measured on the horizontal WSP cards.

Percent Area Coverage

The percent area coverage by distance and treatment from the in-swath and downwind edge of swath are shown in Figure 6. The percent area coverage generally decreased as distance downwind from the spray swath increased, except Treatment 2 which had a slight increase at 5 m location. The percent area coverage was correlated to deposition and droplet size. Treatment ($\alpha < 0.0016$) and distance ($\alpha < 0.0001$) effects were highly significant. Treatment 3 had the largest coverage area at -5 m location, which was under the aircraft. The mean percent area coverage values were 1.51, 1.39, 2.24, 1.81, and 2.40% for Treatments 1-5, respectively. Treatment 2 (EC Blank) had the smallest percent area coverage compared to other treatments.

For percent area coverage (Table 4), Treatments 3, 4 and 5 were significantly different and higher than treatment 2 (EC blank). There were no significant differences between treatments 1 and 2.

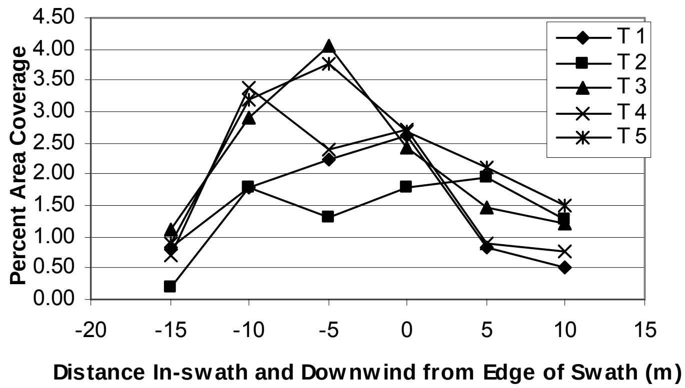


Figure 6. In-swath and downwind coverage as measured on horizontal WSP cards. The centerline of flight was at -10 m (33 ft).

Number of Drops Measured by DropletScan

The number of drops by distance by treatment from the in-swath and downwind edge of swath are shown in Figure 7. The number of drops generally decreased as distance downwind from the spray swath increased. Again, treatment (α <0.0004) and distance (α <0.0001) effects were highly significant effects. Treatment 3 had the largest number of drops at the -5 m location. The mean number of drops was 611, 761, 915, 573, and 602 for Treatments 1-5, respectively. Treatments 1, 3 and 5 were significantly different than Treatment 2 (EC blank). There were no significant differences between Treatments 1, 4, and 5.

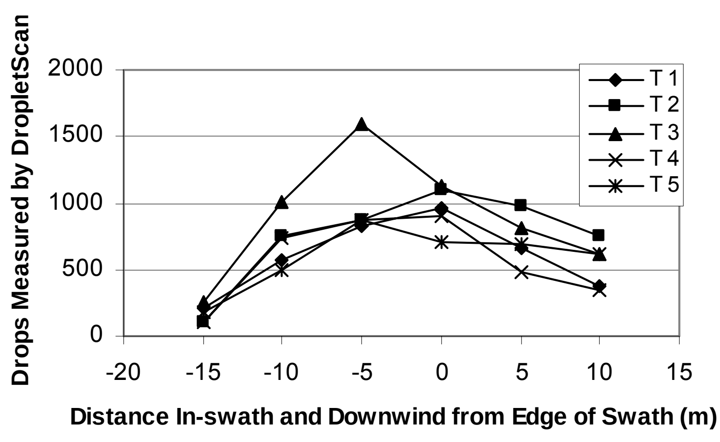


Figure 7. In-swath and downwind number of drops as measured on horizontal WSP cards. The centerline of flight was at -10 m (33 ft).

Monofilament Line Samplers at 50 m (186 ft)-Vertical String Tests

Deposition on the monofilament lines generally decreased as sampling height increased for each treatment (fig. 8.). Treatment 2 had the highest deposition for all the heights. Treatments 3, 4 and 5 had almost the same deposition at the 10 m height. Treatment 5 had the lowest deposition at the 2 and 5 m height. For the test conditions used in this study, the addition of a spray adjuvant resulted in significantly lower airborne deposition. This reduction correlated well with the increase in droplet size as a result of the addition of the spray adjuvants.

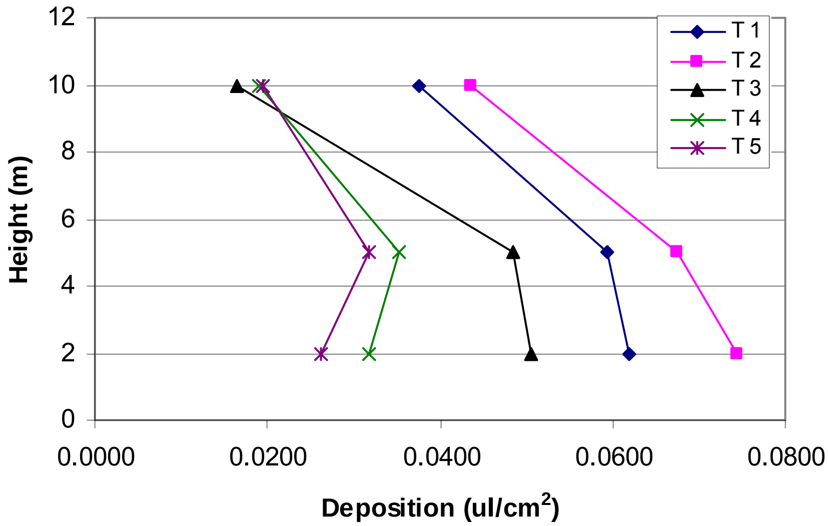


Figure 8. Deposition by treatment on monofilament lines placed 50 m (82ft) downwind from the swath edge at three heights (2, 5, and 10 m).

Conclusions

Mean wind speeds were consistent across all test treatment replication combinations. Mean temperature and relative humidity values remained fairly constant with temperature gradually increasing and relative humidity gradually decreasing as the day progress.

For in-swath and downwind deposition as measured by the mylar plates, there was essentially no deposition beyond 25 m (82 ft). Treatments 3 and 5 had the least downwind deposition, while treatment 4 had the greatest deposition.

Treatment and distance had significant effects on deposition, $D_{V0.5}$, percent area covered, and number of drops, as measured by the WSP. For deposition, all the treatments were significantly different from treatment 2 (EC blank), with treatments 3 and 5 resulting in the highest deposition amounts and treatments 1 and 2 resulting in the lowest. For VMD, treatments 1, 4 and 5 were significantly different than treatment 2 (EC blank) with treatment 5 having the largest measured VMD and treatment 2 the lowest. For percent area coverage, treatments 3, 4 and 5 were significantly different than treatment 2 (EC blank) with treatment 3 resulting in the largest percent area coverage. For number of drops measured, treatments 1, 3 and 5 were significantly different than treatment 2 (EC blank) with treatment 3 resulting in the largest number of drops measured.

Deposition on the monofilament lines decreased as sampling height increased for each treatment. For the test conditions used in this study, the addition of a spray adjuvant resulted in significantly lower airborne drift.

Applicators should be cautious when selecting adjuvants to alter the performance of spray systems. The first line of defense in reducing off target deposition and product efficacy should always be proper system setup and operation. The addition of adjuvants can alter spray performance such that the on and off target deposition, spray droplet size, and deposition characteristics are either lesser or greater than would result from the same tank mix without the adjuvant.

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